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Optimal Multilevel Randomized Quasi-Monte-Carlo Method for the Stochastic Drift-Diffusion-Poisson System

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Abstract

In this paper, an optimal multilevel randomized quasi-Monte-Carlo method to solve the stationary stochastic drift-diffusion-Poisson system is developed. We calculate the optimal values of the parameters of the numerical method such as the mesh sizes of the spatial discretization and the numbers of quasi-points in order to minimize the overall computational cost for solving this system of stochastic partial differential equations. This system has a number of applications in various fields, wherever charged particles move in a random environment. It is shown that the computational cost of the optimal multilevel randomized quasi-Monte-Carlo method, which uses randomly shifted low-discrepancy sequences, is one order of magnitude smaller than that of the optimal multilevel Monte-Carlo method and five orders of magnitude smaller than that of the standard Monte-Carlo method. The method developed here is applied to a realistic transport problem, namely the calculation of random-dopant effects in nanoscale field-effect transistors.

Keywords: Multilevel randomized quasi-Monte-Carlo, multilevel Monte-Carlo, randomized quasi-Monte-Carlo, optimal numerical method, stochastic partial differential equation, field-effect transistor.

1. Introduction

Calculating the expected value of the solution of the stochastic drift-diffusion-Poisson system poses a computational challenge due to the large number of stochastic dimensions in realistic applications. In order to speed up the convergence of the standard Monte-Carlo method, variance-reduction methods such as the multilevel Monte-Carlo method have been developed [1, 2, 3, 4, 5, 6, 7] and have also been applied to the stochastic drift-diffusion-Poisson system [8]. In [8], the parameters of the numerical approach were also optimized such that the total computational work is minimized, while an estimate of the total error is kept below a prescribed tolerance.

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